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# REPORT ON POLLUTION OF INTERSTATE WATERS OF THE LOWER COLUMBIA RIVER, BONNEVILLE DAM TO CATHLAMET, WASHINGTON

Public Health Service
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Report On

# POLLUTION OF INTERSTATE WATERS OF THE LOWER COLUMBIA RIVER BONNEVILLE DAM TO CATHLAMET, WASHINGTON

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U. S. Department of Health, Education, and Welfare
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# FOREWORD

This report reviews the facts of pollution of the interstate waters of the lower Columbia River between Bonneville Dam and Cathlamet, Washington.

Information on which the report is based was assembled from existing reports and files, through discussions with agencies having responsibilities for and intimate knowledge of various facets of the situation, and by personal observations of important features involved.

The following agencies contributed portions of the assembled material:

State of Oregon

- Sanitary Authority
- Board of Health
- Fish Commission
- Game Commission
- Park Commission

State of Washington

- Pollution Control Commission
- Department of Public Health
- Department of Fisheries
- Department of Game
- Department of Parks and Recreation
- University of Washington

City of Portland

- Sewage Disposal Plant

City of Vancouver

- Sewage Treatment Plant

Fisheries Organizations

- Columbia River Packers Association
- Columbia River Fishermen's Protective Association

Industries

- Crown Zellerbach Corporation
- Weyerhaeuser Timber Company

United States

Corps of Engineers, Portland Division
Fish and Wildlife Service
Geological Survey
Coast Guard
Public Health Service, Portland Office

Especial acknowledgment is due the Oregon Sanitary Authority and Board of Health and the Washington Pollution Control Commission and Department of Public Health for their cordial cooperation in providing much of the basic data used in this report and in supplying additional valuable information based on their intimate knowledge of the local situation. Of the other agencies the Corps of Engineers, in particular, furnished a great deal of useful background information.

Responsibility for assembling and interpretation of data and preparation of the report was assigned to F. W. Kittrell, In Charge, Stream Sanitation Studies, Robert A. Taft Sanitary Engineering Center, U. S. Public Health Service.

# REPORT ON
# POLLUTION OF INTERSTATE WATERS
# OF THE COLUMBIA RIVER
# BONNEVILLE DAM TO CATHLAMET, WASHINGTON

## BACKGROUND

The Columbia is the second largest river in our Country. It rises in the Province of British Columbia, Canada, crosses into the United States near Boundary, Washington, and flows in a generally southerly direction across the State of Washington to State Line, Oregon, where it becomes the boundary between Oregon and Washington as it flows toward the west to join the Pacific Ocean.

As the Columbia flows over 1,200 miles through its 259,000 square mile drainage area it accumulates enough water to discharge an average annual flow of nearly 200,000 cubic feet per second (cfs) at its mouth.

The section of the lower Columbia River with which this report deals, from Bonneville Dam to Cathlamet, Washington, has many important uses. The uses of the river are in keeping with its size. It is used, to a greater or a lesser degree, for nearly every purpose that a river can serve. It serves as the source of domestic and industrial water supplies. It is a beautiful river with high scenic value, especially in the Columbia River Gorge below Bonneville Dam. At Bonneville the river produces power. Its cool, clear waters are attractive to boating enthusiasts, swimmers, and water skiiers. Some trappers take fur bearing animals from its waters as a profitable hobby and many hunters shoot ducks on and in the vicinity of the river. Its tremendous runs of salmon and other anadromous fishes provide income for commercial fishermen and recreation for sport fishermen. Adult fishes use the Columbia in traveling upstream to spawn in tributary streams and fingerlings use it in traveling to the sea. Many ships and smaller craft, from ocean-going liners and naval vessels to small outboard motor and sail boats, ply its waters. Large log rafts are both transported and stored on its surface, from which they are withdrawn to feed the numerous, large wood products industries in the area. A few farms are irrigated with water pumped from the river. These are principally vegetable produce farms. Shellfish are taken from the brackish water at its mouth. Finally, the Columbia receives and carries away the sewage and industrial wastes from the municipalities and industries along its banks.

As is inevitable when a single stream is used by many for a variety of purposes there are conflicting interests and needs among the users. This report deals with the area of conflict where interstate pollution affects water uses.

## THE AREA

The section of the lower Columbia River from Bonneville Dam to Cathlamet, Washington, with which this report is concerned, is shown in Figure I (Appendix). This 104 mile reach is more highly developed than any other comparable length of the main river.

Along its banks live nearly a half million people, of whom about three-fourths live in the one city of Portland, Oregon. The other principal cities are Vancouver and Longview, Washington, with populations of about 42,000 and 20,000, respectively. These three are the largest cities on the main river. There are totals of 12 sewered communities and 9 small miscellaneous sewerage systems. Several small towns are without sewerage.

Varied types of manufacturing contribute toward a balanced economy for the region. Power produced from the river has brought many electrometallurgical plants to the area. There are numerous food processing plants. Wood products plants as a group constitute the major manufacturing industry. Of these the pulp and paper mills are a principal factor in pollution of the river.

Income from fishing is important in the area's economy. The Columbia is justly famed for its salmon and steelhead trout. In fact these two species of fish are so plentiful that most commercial and sport fishermen look with disdain on all other kinds of fish, even those which are highly prized in other less favored sections of the Country.

Excellent water transportation contributes to the prosperity of the area. Although Portland is over 100 miles from the ocean the Columbia makes it one of the important ports of the Pacific Coast.

This section of the Columbia is subject to tidal action as far upstream as Bonneville Dam. The tidal range at Portland is small, not exceeding one foot.

## WATER USES

The lower Columbia, as noted earlier, is used for almost every purpose that a stream can serve.

The following descriptions include examples of quantities and values of the uses. These examples are not intended to be all-inclusive. They do, however, serve a useful purpose in helping to place the relative importance of the uses in proper perspective.

## Domestic Water Supply

The lower river is used as the source of two domestic water supplies. One at Clifton, Oregon, serving only about 12 homes, is so small that it does not come under the jurisdiction of the Oregon State Board of Health. Clifton is several miles downstream from Puget Island. Although it is not within the section of the river dealt with in this report, its source of water supply is subjected to bacterial contamination by sewage from the towns covered by the report.

At Longview, Washington, the Weyerhaeuser Timber Company domestic and industrial water supply comes from the Columbia. The domestic water for this plant's 1,000 employees is part of the 85 million gallons per day (mgd) pumped from the river and treated for industrial as well as domestic use by the Pulp Division of Weyerhaeuser. The water treatment provided is the conventional chemical coagulation, sedimentation, and rapid sand filtration, preceded and followed by chlorination. Chlorination is carried to a free chlorine residual.

## Industrial Water Supplies

The other major industrial user of water from the lower Columbia, in addition to the Weyerhaeuser Timber Company, is the Longview Fiber Company pulp and paper mill at Vancouver, Washington. This plant uses about 35 mgd.

Other known industrial water supplies taken from the Columbia are quite small.

## Recreation

There are many recreational uses of this section of the Columbia River. Some of the uses are reasonably well organized and subject to some type of control, but others are pursued on an unorganized and informal basis, and frequently by lone individuals. This makes it difficult to delineate some of the uses and to evaluate their importance fully.

### Sport Fishing

One of the outstanding uses of the river is sport fishing. The salmon and steelhead trout of the Columbia are highly prized by anglers.

The experienced fisherman on the Columbia seeks certain types of

locations for his sport. He has learned by experience that the migrating fish pass close to sand bars of a particular configuration with the river current passing in a certain pattern. He claims to know, within a very few feet, where his lure should be placed for best results. At such spots the sport fishermen stand almost elbow to elbow when the fish are running. Others travel to selected spots by boat. It is estimated that there are at least 25 such spots along the river below the Portland-Vancouver area.

The Washington Department of Fisheries and the Oregon State Game Commission have cooperated in counts of sport fishermen and creel censuses. They estimated that during July 15 through September 2, 1957, 13,000 boat trips and 49,000 fishing trips were made by anglers. The catch consisted of 19,000 chinook, 35,000 silver, and 180 humpback salmon for a total of over 54,000 salmon. Estimates of the money spent on this recreation are not exact, but range from a minimum of $1,350,000 to as high as $2,100,000. The latter figure is based on the estimate that the 700,000 pounds of fish taken cost the anglers an average of $3.00 per pound.

Estimates on steelhead trout catches are not so complete as for salmon. A creel census by the Oregon State Game Commission for a recent summer season of June through the middle of September at one favorite fishing spot indicated that about 2,800 steelhead were taken there during that period. There are 25 to 30 similar areas on the lower river, which indicates that the total catch may have been somewhere near 75,000. The cost to the angler is estimated to be $4.50 per pound for steelhead, compared to $3.00 per pound for salmon.

## Pleasure Boating

There are numerous boat moorages on the lower Columbia River. A major concentration of moorages extends along the Oregon bank from near the upper end of Government Island to below International Bridge. Three other main river moorages on the Oregon side are at Jantzen Beach Park on Hayden Island, at St. Helens, and just below the Longview Bridge. On the Washington side there are moorages just above Camas, at Vancouver, near the mouth of Lewis River across from St. Helens, and downstream from Longview.

The U. S. Coast Guard licenses boats of 16 feet or longer. There are about 2,500 such licensed boats on the lower Columbia. A representative of the Coast Guard has estimated there are about four times this number, or 10,000, unlicensed smaller craft on the river.

Some of these 12,500 craft are commercial, but the pleasure boats constitute the majority.

## Swimming

Much of the swimming and water skiing in the lower Columbia is above the Portland and Vancouver area in the vicinity of the boat moorages which extend upstream to Government Island, and in the vicinity of Jantzen Beach on Hayden Island above the Interstate Bridge. There is swimming and water skiing below the Portland-Vancouver area, however. Reeder Beach on Sauvie Island, about 8 miles below the Portland sewage plant outfall, is a popular center of water recreation. There is other, though less organized, use of the river for swimming and water skiing on downstream to Cathlamet. Two bathers were observed recently on the river side of Hayden Island below and within about 1,000 feet of the point where Portland's sewage discharges. These bathers undoubtedly were typical of many persons who swim alone or in small groups on an unorganized basis throughout the section of the main river between the Portland-Vancouver area and Cathlamet.

## Hunting

The lower Columbia is popular with duck hunters, who use boats for traveling to and from their shooting grounds. Downed birds are retrieved from the water. The lower end of Sauvie Island is especially popular for this sport.

Complete data defining this use of the Columbia are not available. It is estimated by the Washington Department of Game that over 100,000 ducks were killed in the four Washington counties bordering the lower Columbia during the 1956-1957 season. It is probable that not more than one-half of these were killed on the Columbia. Kills average a little better than nine ducks per hunter per season. If it be assumed that duck hunting was about the same on the Oregon side it is indicated that something like 10,000 duck hunters used the lower Columbia. It is estimated that the average waterfowl hunter spends about $41.00 per season. This indicates a total expenditure of more than $400,000 per year for duck hunting on the lower Columbia River.

## Trapping

There is a limited amount of trapping on the lower Columbia. About 7,500 muskrat pelts were taken in the four Washington counties bordering this section of the river during the 1956-1957 season. Adjustment of these data on the same basis as was used in estimating total duck hunters indicates that more than $8,500 worth of muskrat pelts were taken from the lower Columbia by Washington and Oregon trappers.

Trapping for income may not appear to be recreation. The small cash income from this source on the Columbia indicates that those who trap do so as a hobby rather than as a profession. In this case it is thought proper to classify it as a form of recreation.

## Navigation

More than 60 percent of all navigation on the entire Columbia River during 1956 was limited to the lower river, from the Portland-Vancouver area to the mouth. During that year nearly 22,400,000 tons of cargo was hauled between those two points. This was equivalent to nearly 1.5 billion ton miles of haulage.

Large numbers of log rafts are transported on the river for the lumber and pulp and paper plants in the area. The logs, while awaiting use, are stored in quiet areas along the river banks and in sloughs on either side of the river. Most of the storage areas are between Camas and Cathlamet, Washington, with only a limited amount of storage between Camas and Bonneville Dam.

## Irrigation

Although irrigation is a major use of the upper reaches of the river there is only a small amount of irrigation along the lower Columbia. Water is pumped from the river for this purpose at possibly 25 or 30 points between Bonneville Dam and Cathlamet. The water is used principally to irrigate vegetable produce. As one example, on Sauvie Island, celery, strawberry, and bean crops are irrigated with water taken from the river.

## Power Production

The power plant at Bonneville is equipped with 10 Kaplan turbine-generator units with a total rated capacity of approximately 518,400 kilovatts at 0.9 power factor. This plant produces an important portion of the total power produced in the Columbia River Basin.

A navigation lock at the dam provides a minimum 27 foot depth through which large vessels may pass upstream to the Dalles and small craft, such as barges, may continue on to Lewiston, Idaho, on the Snake River.

Fish ladders on both the Oregon and Washington sides of the river allow migrating fish to mount the dam into Bonneville Pool and pass on

upstream to their spawning grounds. Counts of the migrating fish have shown mean numbers ranging from a little less than 2,000 to a little more than 10,000 per day since 1938, when the dam was completed.

Bonneville Dam is the control point for flow of the river downstream through the section of the Columbia River with which this report deals. The Bonneville Pool provides little storage, and has relatively little effect on average daily flow of the river. It can control the hourly flow, especially during periods of low flow. When flows drop below 135,000 cfs the power generators are operated on a peaking schedule. The result is that flow below Bonneville Dam is greater than the daily average when the generators are in full operation, and lower than the daily average when they are cut back. An example of the effect of this type of operation is shown by a chart provided by the Portland District Office of the U. S. Corps of Engineers. This chart shows discharges below Bonneville Dam for selected times during the period January 20 through February 15, 1949. On 23 of the 27 days involved flows below Bonneville were as low as 42,000 cfs, or lower, for several hours of each day. One recorded flow was as low as 22,000 cfs, and on 8 days flows below 30,000 cfs were recorded. The lower flows usually lasted from 7 to 9 hours each day. Possible implications of this are discussed in the subsequent section on commercial fishing.

## Commercial Fishing

The over-all Columbia River fishery is extremely valuable to the area. In recent years it has been estimated to yield a return of $20,000,000 annually. A capital investment of $500,000,000 at 4 percent interest would be required to provide this annual income.

Not all of this income, of course, accrues to the lower Columbia River area, but an important fraction of it does. Most of the commercial fishermen employ gill nets. In 1957 about 800 gill net licenses were issued to Columbia River fishermen in Washington and Oregon. The average income for the commercial fisherman is about $5,000 per year. The total income for the group is estimated to have been about $4,000,000. The value of the processed fish is estimated to be approximately twice the price paid to the fishermen, or about $8,000,000 in 1957.

In 1957 the value of nearly 6,380,000 pounds of canned salmon and steelhead from the Columbia was reported to be $5,500,000. In addition 2,800,000 pounds of salmon and steelhead from the Columbia were processed as frozen fish. At an average of $0.85 per pound the value of the frozen fish would have been $2,400,000. This gives a total processed fish value of $7,900,000 in 1957. This is in good agreement with the preceding estimate of $8,000,000 based on income to commercial fishermen.

Returns from various phases of the fishing industry constitute the principal source of income for the 12,000 population of Astoria,

Oregon, which is the center of the lower Columbia River fishery. Some of the town's income is derived from the ocean fishery, as well as that of the Columbia.

The average commercial fisherman in this area is estimated to have about $3,500 invested in boat, gear, and other equipment. The 800 gill netters thus would have an investment of about $2,800,000. In addition, the fishermen employ divers to remove snags from the river bottom in the drifts where they use gill nets. It is estimated that this operation cost about $85.00 per drift in 1957. For the 78 drifts between Bonneville Dam and Cathlamet the total annual cost on this basis was about $6,600.

The value placed on the Columbia River fisheries by responsible governmental agencies is shown by the money spent by these agencies to protect this resource. It is estimated that the States of Washington and Oregon and the Federal Government have spent nearly $50,000,000 in the past 10 years for fishery protective measures.

## SOURCES OF WASTES

Most of the wastes contributing to pollution of the lower Columbia River originates in communities and industries situated on or near the banks of the river between Camas and Cathlamet, Washington. The quality of water reaching Bonneville Dam is excellent, and available information indicates that most of the tributaries carry relatively little pollution at their confluences with the Columbia.

Samples are collected and analyzed weekly at Bonneville Dam in connection with the Public Health Service National Water Quality Basic Data Program. Twenty-four samples examined for coliform organisms since January 1958 yielded an average MPN of 51 per 100 milliliters of water. The maximum single MPN reported was 220 per 100 ml. The 5-day biochemical oxygen demand has averaged 1.1$^{4}$ ppm, and dissolved oxygen saturation has been between 92.9 and 115 percent. These data indicate that the sanitary quality of the river water at Bonneville is good and that pollution from upstream does not contribute significantly to pollution of the lower Columbia.

With the exception of the Willamette River the streams tributary to the lower Columbia receive only relatively minor quantities of wastes and are not believed to exert any appreciable effect on the main river. The Willamette River above Portland receives large quantities of wastes. This report is not dealing with water quality in intrastate waters of the Willamette itself, but the Willamette at its mouth is recognized as a potential source of pollution affecting the interstate waters of the Columbia River. Available data on coliform organisms indicate that the Willamette probably does not contribute important bacterial contamination

to the Columbia. Data are not available for this report which will permit evaluation of the role of the Willamette in daily contributions to the Columbia of either nutrients that will support slime growths or of floating slimes which drift into the main river. There is some evidence that freshets on the Willamette intermittently, and for short periods, flush floating slimes into the Columbia. No definite conclusion regarding the quantitative importance of the Willamette River in the over-all pollution problem of the Columbia River is possible at this time.

The two types of wastes, from sources along the river, causing stream pollution which interferes with water uses in the lower Columbia River are sewage and industrial wastes. The sewage carries pathogenic bacteria into the river, with resultant health hazards to those who have contact with the water. Both sewage and industrial wastes contain certain organic compounds which support excessive growth of non-pathogenic bacterial growths, or slimes (Sphaerotilus), in the river, which interfere with fishing.

## Sources of Bacterial Contamination

Most of the domestic sewage from towns and industrial plants along the lower river receives a minimum of primary treatment. On the Washington side most of the sewage is chlorinated in addition. Little of the sewage on the Oregon side is chlorinated. Figure I (Appendix) shows the known sources of sewage in the area and the types of treatment provided.

A common unit for expressing the strength of sewage is the population equivalent (P.E.) based on oxygen demand. While this unit serves as a basis for comparing the relative oxygen depleting characteristics of organic wastes, it does not provide a basis for comparing the bacterial content of sewage from various sources. Expression of the strength of sewage in bacterial population equivalents (B.P.E.) is more useful than oxygen demand population equivalent in evaluating the relative responsibilities of the several sources of sewage for bacterial contamination of the river.

Little actual data are available on the bacterial contents of the sewage effluents from the sources shown in Figure I (Appendix). It is assumed that the B.P.E. of raw sewage is the same as the sewered population. Where primary treatment is provided the B.P.E. of the treated sewage effluent is assumed to be 50 per cent of the sewered population. The B.P.E. of chlorinated effluent from a primary or intermediate plant, and of effluent from a secondary plant is assumed to be 10 per cent of the sewered population. The 10 per cent value may be considered high for some of the plants which chlorinate since it is possible to kill 99 per cent or more of the bacteria in sewage if facilities for chlorination are well designed and operated. In the case of Vancouver, the largest source of sewage on the Washington side, the chlorine is introduced into

the outfall line from the plant with no special facility for mixing, and the only contact time is the 6 to 8 minutes the sewage is in the outfall line before it reaches the river. These facilities do not meet good design requirements for chlorination, and efficiency of disinfection may be expected to be relatively poor. On the basis of this and other information on chlorination practices in this area the assumed 90 per cent kill of sewage bacteria for the treatment plants having chlorination is believed to be reasonable.

On the basis of the above considerations the estimated B.P.E.'s of sewage from the various sources, shown in Table I (Appendix), have been computed. Salient features of this detailed tabulation are summarized in Table 1.

Table 1

Summary of Bacterial Population Equivalents
of Sewage Discharged to Lower Columbia River

| Source | Bacterial Population Equivalent | |
|---|---|---|
| | Number | Per Cent of Total |
| Oregon | | |
| Portland | 140,000 | 89.57 |
| St. Helens | 4,500 | 2.88 |
| Six Other Sources | 2,230 | 1.42 |
| Total Oregon | 146,730 | 93.87 |
| Washington | | |
| Vancouver | 4,760 | 3.05 |
| Longview | 2,400 | 1.54 |
| Twelve Other Sources | 2,440 | 1.54 |
| Total Washington | 9,600 | 6.13 |
| Total All Sources | 156,330 | 100.0 |

This table indicates that nearly 94 per cent of the bacterial contamination is discharged from the Oregon side, and only a little more than 6 per cent from the Washington side. Portland alone contributes an estimated 89.6 per cent of the total. Portland, Oregon, and Vancouver, Washington, contribute a combined 92.6 per cent of the total to the river.

The other 18 sources contribute only 7.4 per cent of the total. These other sources are rather widely dispersed through the 100 mile section of river involved.

The combined effect of sewage treatment by all Washington communities is to reduce coliform organisms by an estimated 88.5 per cent. The comparable over-all reduction for Oregon communities is only 50.1 per cent.

The bacterial content of all sewage discharged to the river is estimated to be equivalent to that of the raw sewage from about 155,000 persons.

## Sources of Orgnaic Wastes

The industrial wastes discharged to the lower Columbia River may be divided into two broad groups, depending on the absence or presence of organic compounds in the wastes.

The industries producing wastes which contain little or no organic compounds are typified by the electrochemical and metallic products plants. No evidence associating these wastes with adverse effects of interstate pollution was obtained while assembling material for this report. The 10 plants of this group in the area will not receive further consideration at this time.

In addition to the organic matter in sewage from towns in the area, there are 20 industrial plants discharging wastes containing organic matter directly to the Columbia. Most of these are pulp and paper mills and food processing plants. It is customary practice to express the relative strengths of organic wastes in terms of biochemical oxygen demand. The unit in which the strengths are expressed is termed the population equivalent (P.E.). The P.E. for a given waste is the number of persons that would be required to produce sewage having the same 5-day biochemical oxygen demand as that of the organic waste.

Information is available to permit computations or estimates of P.E.'s for 17 of the 20 plants which discharge organic wastes. If information were available from the other three plants it is not believed that either the over-all figures or subsequent conclusions would be changed materially.

Figure II (Appendix) shows plant locations and Table II (Appendix) gives details of available information on P.E.'s of sewage and organic industrial wastes discharged to the river. Salient features of these data are summarized in Table 2.

Table 2

Summary of Oxygen Demand Population Equivalents
of Sewage and Industrial Wastes Discharged
to Lower Columbia River

| Source | Oxygen Demand Population Equivalents Number | Per Cent of Total |
|---|---|---|
| Oregon | | |
| Portland Sewage | 218,000 | 6.78 |
| Kaiser Gypsum Company, Inc. | 100,000 | 3.11 |
| Crown Zellerbach Corporation | 150,000 | 4.66 |
| Twelve Other Sources | 31,870 | 0.97 |
| Total Oregon | 499,870 | 15.52 |
| Washington | | |
| Vancouver Sewage | 29,150 | 0.90 |
| Longview Fiber Company | 216,000 | 6.72 |
| Weyerhaeuser Timber Company | 407,000 | 12.66 |
| Columbia River Paper Mill | 431,000 | 13.40 |
| Crown Zellerbach Corporation | 1,500,000 | 46.65 |
| California Packing Company | 76,000 | 2.36 |
| Washington Canners Corporation | 20,500 | 0.64 |
| Twenty Other Sources | 35,140 | 1.15 |
| Total Washington | 2,714,790 | 84.48 |
| Total All Sources | 3,214,660 | 100.0 |

This table indicates that 84.5 per cent of the total organic wastes are discharged from the Washington side of the Columbia, and 15.5 per cent from the Oregon side. In Table II (Appendix) it is shown that all sewage from both states accounted for only 9.0 per cent of the total organic wastes, compared to 91.0 per cent for the industrial wastes. Of the total, the six pulp and paper mills accounted for 87.2 per cent, leaving 12.8 per cent attributable to all other sources. One pulp and paper mill, Crown Zellerbach Corporation at Camas, Washington, accounted for 46.7 per cent of the total. This one mill produced 53.6 per cent of the total P. E. of all the pulp and paper mills.

The above data are for sources of wastes on or adjacent to the river and do not include one significant waste that is discharged to the

Columbia. The Publishers Paper Company at Oregon City, Oregon, on the Willamette River, barges sulfite waste liquor to the Columbia River during periods of low flow in the Willamette River, which usually occur in the months of July through October. This waste, consisting of about 330,000 gallons per day of sulfite waste liquor, is pumped from the barges into the Columbia below the mouth of the Willamette. This waste adds about 400,000 P.E. to the total of 3,214,700 from all sources situated along the Columbia. It was not included in the previous data because of its unusual method of entering the river. It is discharged in a few hours time each day during the limited period of the year when this unusual means of disposal is practiced. It adds to the pollution problem in the Columbia, and will be considered in the discussion of effects of pollution.

## EFFECTS OF POLLUTION

Two major results of pollution account for the principal interferences with water uses that are attributable to pollution. Both results of pollution involve bacteria. One result is the health hazard caused by use of water contaminated with pathogenic bacteria and other microorganisms carried into the river by sewage. The other result is the interference with fishing by non-pathogenic bacterial slimes nourished by the organic wastes.

### Health Hazards

The Pollution Control Council, Pacific Northwest Area, has established objectives of water quality for protection of the health of water uses in this area. The Council includes representatives of water pollution control and public health agencies of British Columbia, Alaska, Idaho, Montana, Oregon, and Washington, and of the Canadian Department of National Health and Welfare, and the U. S. Public Health Service.

#### Water Quality Objectives

The following objectives recommended by the Council are applicable to bacterial quality in the lower Columbia River:

1. Source of Domestic Water Supply With Conventional Treatment

   The most probable number (MPN) of coliform organisms, when associated with domestic sewage, of a representative

number of samples should average less than 2,000 per 100 milliliters (ml.), and should not exceed this number in more than 20 per cent of samples examined in any month.

2. Water Used for Boating and Fishing

The MPN of coliform organisms, when associated with domestic sewage, of a representative number of samples should average less than 1,000 per 100 ml., and should not exceed this number in more than 20 per cent of the samples examined.

3. Water for Swimming

The MPN of coliform organisms, when associated with domestic sewage, of a representative number of samples should average less than 240 per 100 ml., and should not exceed this number in more than 20 per cent of the samples examined.

4. Minimum Treatment Requirements for Domestic Sewage

The minimum treatment required for domestic sewage discharged into waters used for water supply for drinking, and for bathing, swimming and recreation is sedimentation and effective disinfection.

## Bacterial Water Quality

Records of bacterial quality of water in the lower Columbia River are available from numerous sources extending back at least to 1940. Those previous to 1953, however, are not representative of present river conditions. Progress in sewage treatment in this area has been excellent since 1950. In 1952 the City of Portland provided primary treatment, but not chlorination, with the treated sewage discharged across Hayden Island to a point in the Columbia about 1,000 feet below the S. P. and S. R. R. Bridge (Mile 105.2). Portland sewage accounts for 89.6 per cent of the total B.P.E. discharged to the lower Columbia. This source dominates the pattern of bacterial contamination in the river. Thus, only data on bacterial quality obtained since 1952, after the Portland sewage plant started operation, are applicable to present conditions.

Employees of the Portland Sewage Treatment Plant sample the river at one station above and three stations below the point where the sewage is discharged. The sampling station farthest downstream (Mile 100.0) is about 5 miles below the point of sewage discharge (Mile 105.2). At each station samples are collected near each bank of the river and in the

middle to indicate conditions across the entire river. The voluminous data for the years 1953 through 1957 have been made available for this report through the courtesy of the Superintendent of the sewage plant.

Analysis of the data, on a monthly basis, indicates that bacterial contamination generally is highest in the months of August through November. Figure 1 shows the monthly median coliform MPN values at the sampling station (Mile 103.8) immediately below the Portland-Vancouver area. The high values for the August-November period are obvious on this chart. It should be noted, however, that the water quality objectives for swimming and for boating and fishing were not met at this point in any month of the year.

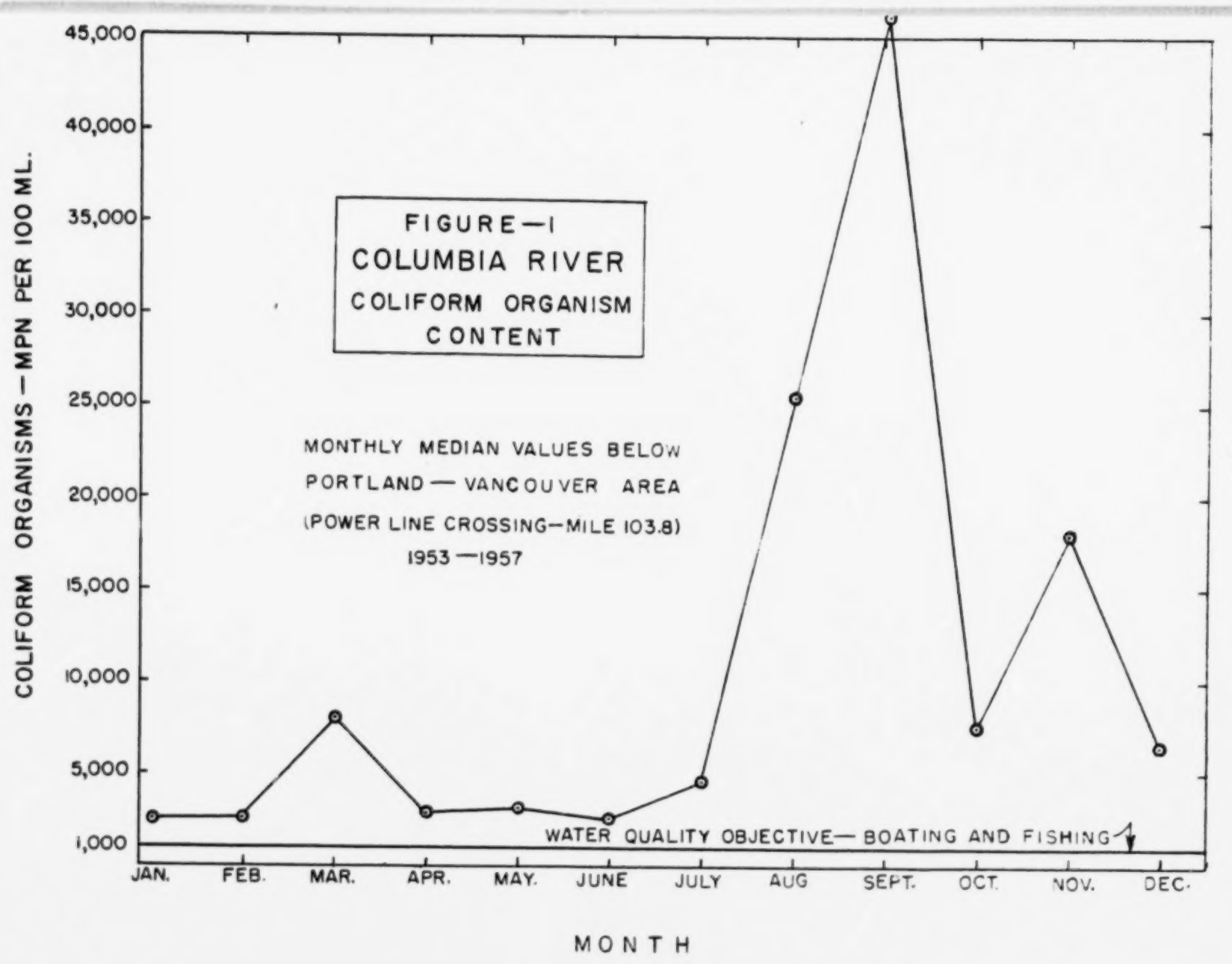
Two factors apparently contribute to the high contamination during this period. Stream flows generally are low and dilution of the sewage is at a minimum. In addition, water temperatures are not so low as they are during the months of December through March when flows normally are low. It has been found at other cities, and is reconfirmed here, that a source of sewage adds only one-fourth to one-third as much bacterial contamination to a stream in winter as it does in summer.

The data indicate that bacterial contamination of the Columbia generally may be expected to be highest when stream flow is in the range of 80,000 to 130,000 cfs and water temperature is above 10° C.

Unfortunately the data available since 1952 do not provide a basis for factual evaluation of bacterial quality downstream from Mile 100.0, which is near the upper end of Sauvie Island, to Cathlamet. It is possible, however, to arrive at reasonable estimates based on: the data for the river in the vicinity of the Portland-Vancouver area; sample results of other Columbia River studies; knowledge of downstream sources of sewage; and experience with other contaminated streams.

The coliform organism curve in Figure 2 has been prepared on the above basis. The median coliform data from the Portland sewage plant for the August through November periods of 1953 through 1956 were plotted as observed points. Below the farthest downstream station at which the observed data are available (Mile 100.0) the probable coliform content of the river has been estimated on the basis of the coliform death rate curve found in another river contaminated with essentially the same concentration of coliform organisms as that observed at Mile 100.0. The curve was adjusted at the St. Helens and the Longview-Kelso-Ranier areas for the computed bacteria added to the river by those areas.

Although the major portion of the curve is theoretical, its general acceptability is supported by data in the Washington Pollution Control Commission 1951 report, "An Investigation of Pollution of the Lower Columbia River" (Technical Bulletin No. 12). A coliform death rate curve developed from data in that report exhibits a slope which is


FIGURE—1
COLUMBIA RIVER
COLIFORM ORGANISM
CONTENT
MONTHLY MEDIAN VALUES BELOW
PORTLAND — VANCOUVER AREA
(POWER LINE CROSSING—MILE 103.8)
1953 —1957
COLIFORM ORGANISMS — MPN PER 100 ML.
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
1,000
WATER QUALITY OBJECTIVE— BOATING AND FISHING
JAN.
FEB.
MAR.
APR.
MAY.
JUNE
JULY
AUG
SEPT.
OCT.
NOV.
DEC.
MONTH

15-b

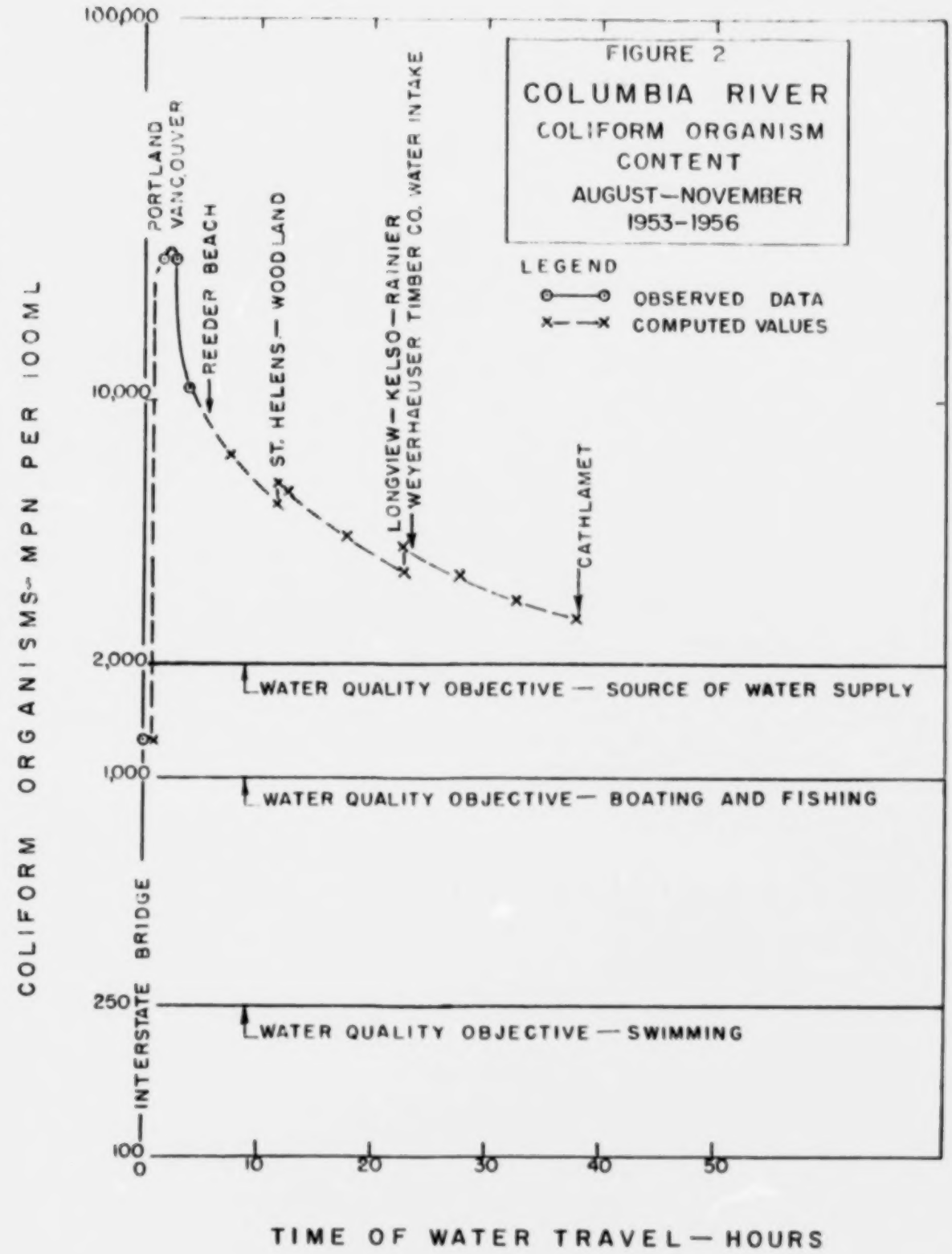


FIGURE 2
COLUMBIA RIVER
COLIFORM ORGANISM CONTENT
AUGUST—NOVEMBER
1953-1956
LEGEND
OBSERVED DATA
COMPUTED VALUES
COLIFORM ORGANISMS- MPN PER 100ML
100,000
10,000
2,000
1,000
250
100
0
PORTLAND
VANCOUVER
REEDER BEACH
ST. HELENS— WOODLAND
LONGVIEW— KELSO— RAINIER
WEYERHAEUSER TIMBER CO. WATER INTAKE
CATHLAMET
INTERSTATE BRIDGE
WATER QUALITY OBJECTIVE — SOURCE OF WATER SUPPLY
WATER QUALITY OBJECTIVE— BOATING AND FISHING
WATER QUALITY OBJECTIVE — SWIMMING
10
20
30
40
50
TIME OF WATER TRAVEL— HOURS

reasonably similar to that of the theoretical portion of the curve in Figure 1. While the theoretical portion of the curve is not quantitatively exact there is reason to believe that it indicates contamination that is lower rather than higher than that which actually occurs.

The curve in Figure 2 does not present the worst probable bacterial contamination of the lower Columbia. The average stream flow on which it is based was 130,000 cfs. Monthly average flows as low as 80,000 cfs are not uncommon during the August through November period. During such months the coliform content should be roughly 50 per cent higher than the values indicated by the curve. On this basis concentrations would range from about 35,000 per 100 ml. just below the Portland-Vancouver area to about 4,000 per 100 ml. at Cathlamet.

## Relation of Bacterial Quality to Water Uses

The bacterial contamination of the lower Columbia River constitutes a health hazard to those who use the water for domestic water supply, for swimming and water skiing, and for the various activities that involve boating. The latter include pleasure boating, fishing, hunting, trapping, navigation, and log transportation.

### Domestic Water Supply

The Weyerhaeuser Timber Company water supply, as previously noted, provides water for domestic use by the plants 1,000 employees. The intake for this supply is near the Washington bank of the Columbia River 38 miles below the Portland-Vancouver area.

Figure 2 indicates that the coliform organism content of the Columbia River at the water supply intake during the August through November period averages about 4,000 per 100 ml., or twice the objective of 2,000 per 100 ml. for a source of domestic water supply. It should be noted that Figure 2 represents average bacterial quality across the entire river at any selected point. Actually the bacterial contamination of the water at the Weyerhaeuser intake is somewhat worse than is indicated by Figure 2. Data on coliform organisms are available from samples of the untreated water submitted to the Washington State Department of Health laboratory. During the August through November periods of 1956 and 1957 the average coliform organism content of 22 samples was nearly 58,000 per 100 ml., with concentrations ranging from 1,100 to 240,000 per 100 ml. The median of the 22 values was between 4,600 and 11,000 per 100 ml. The latter is believed to be more nearly representative of the actual water quality at the intake than is the average for the river at this point.

Nineteen of the 22 samples examined by the Washington Health Department laboratory had coliform organisms in excess of 2,000 per 100 ml. This represents 86 per cent of the samples, or more than four times the 20 per cent limit adopted by the Pollution Control Council.

Vancouver and Cathlamet, Washington, have plans to supplement their municipal water supplies from the Columbia River. Figure 2 indicates that the coliform organism concentration of the Columbia above Vancouver averages less than 2,000 per 100 ml., but at Cathlamet it averages about 3,000 per 100 ml. during the August through November period. The latter concentration is 50 per cent in excess of the Council's objective for a source of domestic water supply.

## Swimming and Water Skiing

Both those who swim and those who water ski almost inevitably swallow some water. Figure 2 indicates that the water ingested would contain bacteria of sewage origin ranging from 23,300 per 100 ml., just below the Portland-Vancouver area, to 2,600 per 100 ml. at Cathlamet. Since 100 ml. is approximately one large mouthful of water the swimmer or skiier could ingest the above numbers of sewage bacteria in one swallow. The concentrations range from 97 to 11 times the water quality objective of 240 per 100 ml.

Figure 2 indicates that the average coliform organism concentration at Reeder Beach, a known swimming area, is about 9,000 per 100 ml. Samples collected throughout a river cross section opposite this beach during September and October 1955, yielded an average coliform organism concentration of 18,700 per 100 ml., or about twice the value indicated by the curve. Similar samples collected about two miles upstream from Reeder Beach during the same period yielded an average of 12,500 per 100 ml., which is closer to the concentration indicated by Figure 2.

## Activities Involving Boating

Boats are used on the Columbia River for pleasure and relaxation, for sport and commercial fishing, for hunting and trapping, and for navigation. All of these activities involve some direct contact with the water, even though it be no more than the spray from the bow of a fast boat speeding over the water.

Figure 2 indicates that the coliform organism concentrations range from 26 times the water quality objective of 1,000 per 100 ml. for this type of water use just below the Portland-Vancouver area, to 3 times the objective at Cathlamet.

## Summary of Bacterial Quality

The data on bacterial contamination of the lower Columbia River indicate that the river water does not meet the bacterial water quality objectives established by the Pollution Control Council for any of the uses made of the river between the Portland-Vancouver area and Cathlamet.

About 92.6 per cent of the bacterial contamination responsible for these hazards to health originate in the sewage discharges of the Portland-Vancouver area, with Portland contributing an estimated 96.7 per cent of the total from the area.

## Interferences With Welfare

In addition to the hazards to health caused by pathogenic bacteria of sewage origin, there are interferences with fishing in the lower Columbia River by non-pathogenic bacteria which flourish on some of the organic wastes.

## Water Quality Objectives

The Pollution Control Council, Pacific Northwest Area, adopted objectives designed to prevent interferences with water uses which would endanger the welfare of the public. The applicable objective in this case deals with floating, suspended and settleable solids and sludge deposits. This objective states that there shall be none of the above materials attributable to sewage, industrail wastes or other wastes or which, after reasonable dilution and mixture with receiving waters interferes with the best use of these waters for various types of water supply, for bathing, swimming and recreation, and for growth and propagation of fish.

## Bacterial Slimes

Some of the organic compounds in sewage and industrial wastes support bacterial slime growths in receiving waters. There are several types of these slimes, of which a common and widespread one is Sphaerotilus. This organism thrives on hexoses, pentoses, organic acids, alcohols and nitrogenous compounds such as amino acids, even when these materials are present in extremely low concentrations. Slime infestations have been found in the presence of fairly high concentrations of sewage, and below dairy, cannery, beet sugar, brewery, slaughterhouse, cellulose acetate, and sulfite and kraft pulp and paper plants. In the absence of artificial pollution with organic materials, slime infestations will not occur.

Under favorable conditions Sphaerolitus attaches to an underwater solid surface and grows as chains, or filaments, of cells surrounded by a sheath. The filaments are encased in gelatinous capsular material. Colonies of the filaments develop into either tufts or plumes. The plumes may be as much as an inch or more in diameter and several inches long. These tufts and filaments may die and break off to float downstream. They also may be broken off by increased velocity of the water. They grow on log rafts tied up along the edge of the Columbia and break off when the logs are removed from the water. These detached slimes float downstream for many miles when stream velocities are sufficient to keep them from settling. They also settle to the bottom in quiet areas of the river. Here they form sludge masses which either decompose or may be re-suspended by increased stream velocities accompanying increased stream flows to drift on downstream.

A characteristic of the slimes is the tendency of the gelatinous masses to become entwined with and cling tightly to objects with which they come in contact in the stream.

## Occurrences of Slimes in Lower Columbia River

Bacterial slimes, or Sphaerotilus, have occurred intermittently in the lower Columbia River for at least 20 years. It has not been possible to establish definitely the year when the slimes first became a problem.

### December 1940 Through April 1942

Complaints caused by the slimes came to the attention of the Oregon State Sanitary Authority and the Washington State Pollution Commission who undertook a cooperative study of the problem. Field work was started in December 1940, and was completed in April 1942. The findings were published in 1943 as a "Report on Investigation of Pollution in the Lower Columbia River." This has become known as the Lincoln and Foster report, after its authors.

This report described the following areas in which the slimes were observed to be growing prolificly during the period of field study. All areas were along the Washington side of the river.

1. Camas Slough in the Vicinity of The Crown Willamette Paper Company (now Crown Zellerbach Corporation) pulp and paper mill waste outfall, and downstream along the river bank as far as Brickyard (Ellsworth), about 6 miles below the mouth of Camas Slough, and about 7 miles above the Interstate Bridge at Vancouver.

2. Immediately below the waste outfall of the Columbia River Paper Mills Company at Vancouver and downstream for a distance of nearly 4 miles.

3. From a point nearly 300 yards above the Weyerhaeuser Timber Company Pulp Mill, just below Longview, downstream almost to Barlow Point, a total distance of about 3 miles.

The authors stated that the slimes grew only in areas where wastes from pulp mills were present in considerable strength. They also confirmed the relation between slime growth and pulp mill wastes by controlled experiments in wooden troughs through which river water, containing various concentrations of pulp mill wastes, flowed continuously.

Based on the experimental trough work the authors concluded that growth of Sphaerotilus in significant amounts occurred when digester liquor from either sulfite or sulfate pulp manufacturing was present in concentrations of 50 ppm or greater. They also concluded that Sphaerotilus grew on fixed objects in the river only where concentrations of fresh digester liquor were consistently in excess of 50 ppm of equivalent sulfite liquor having 10 per cent total solids.

The report stated that floating slime caught on fishermen's nets and inhibited fishing from Camas to the mouth of the Columbia. Fishermen above Camas were not affected by Sphaerotilus at any time.

During the period of the study most prolific slime growth was observed in the months of September, October and November 1941, with the maximum floating slime occurring in November.

Summer 1951

The Washington Pollution Control Commission conducted a study of the lower Columbia River in the summer of 1951. The results of this work were published as a report on "An Investigation of Pollution in the Lower Columbia River."

The authors of that report stated that slime growth was scanty in Camas Slough, below the Crown Zellerbach Corporation waste line, and as far downstream in the Columbia as Fishers Landing, about 2 miles below the mouth of the slough. At Ellsworth, however, about 6 miles below the mouth of the slough, and at McLoughlin, about 8 miles below, prolific growths were observed on boats, logs, pilings and floats. Below McLoughlin the amount of growth decreased downstream to the Interstate Bridge, where only traces were found.

At S.P. & S. R. R. Bridge, about two-thirds of a mile below the Columbia River Paper Mills in Vancouver, a more profuse growth of Sphaerotilus was observed than elsewhere in the survey area. The growing

slime was very much in evidence for a little over 2 miles below the waste outfall.

A limited amount of Sphaerotilus was found in the vicinity of the Longview Fiber Company waste line at Longview. Just below the Weyerhaeuser Timber Company pulp mill waste line slime growths appeared, and were extensive about one-fourth mile below the mill. One mile below the mill growths were present but had diminished considerably.

As in 1941 floating slimes occurred for many miles below the areas of growth.

Unpublished Observations

There have been observations of areas of slime growths since 1951 which have not been published. Among those making such observations have been representatives of the Washington Pollution Control Commission, the Oregon Sanitary Water Authority, and the U. S. Public Health Service.

Summary of Occurrences of Slimes

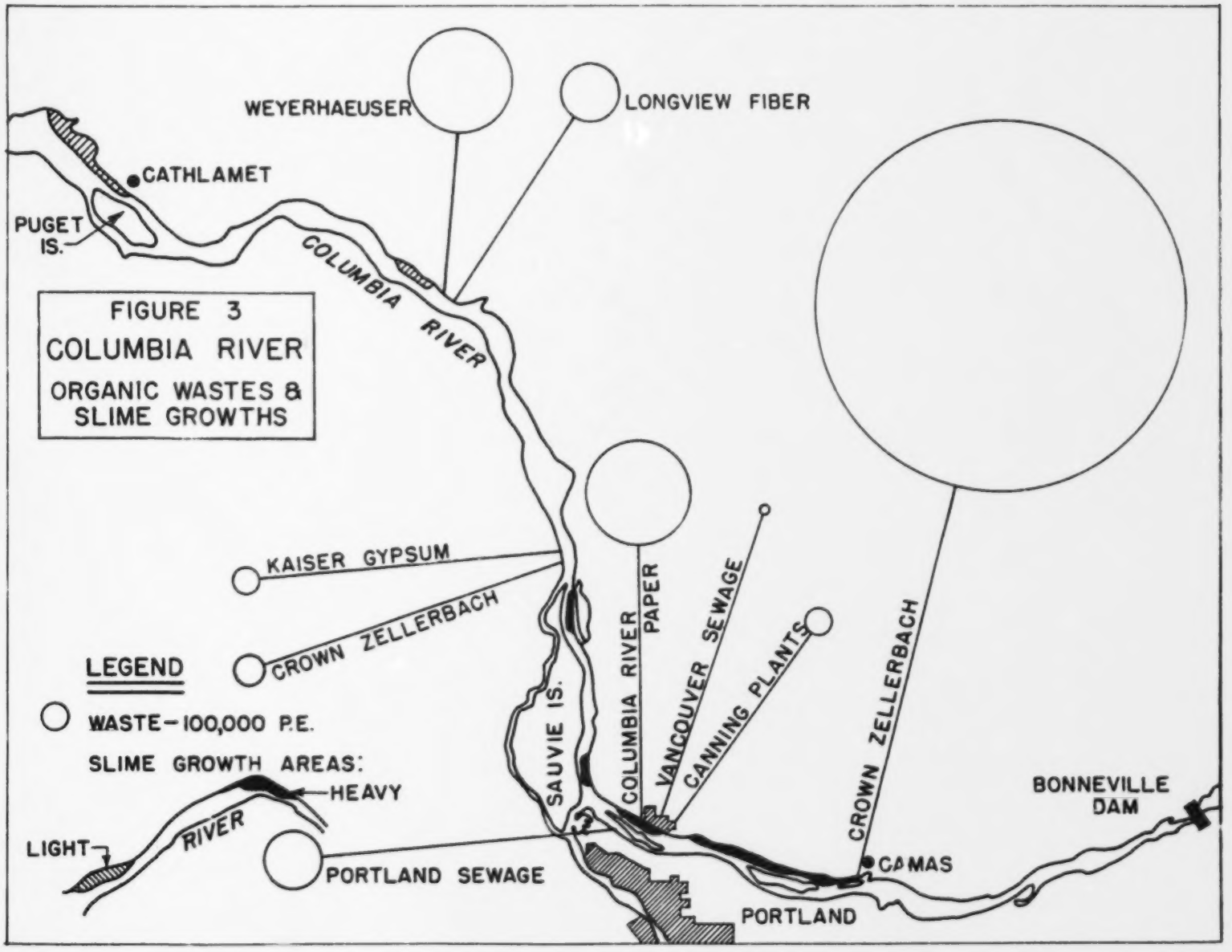
On the basis of the published reports and discussions with individuals who have observed the growing slimes it is concluded that slime growths have occurred in the lower Columbia River in the approximate locations indicated in Figure 3. The reasons for isolated areas of growth well below Vancouver and below Cathlamet are not clear. The river must carry nutrients, principally from the pulp and paper mill wastes, in concentrations adequate to support growth past the intervening areas where slime growths were not observed. It is probable that favorable combinations of nutrients, currents, water velocities, and suitable attachment surfaces coincide only where growths actually occurred.

The published reports, the observations by qualified persons, and complaints by fishermen establish the fact that drifting slimes occur intermittently throughout the entire length of the Columbia from Camas to Cathlamet in quantities that interfere with fishing operations.

Figure 3 also indicates the relative quantities of organic wastes, as measured by oxygen demand, discharged to the river from the major sources of wastes. The quantities, in population equivalents, were given in Table 2, and were discussed in the section on organic wastes.

## Causes of Bacterial Slimes

Observations of slime growths in the Columbia River, controlled experimental growth of slime in river water in the presence of sulfite


WEYERHAEUSER
LONGVIEW FIBER
CATHLAMET
PUGET IS.
COLUMBIA RIVER
FIGURE 3
COLUMBIA RIVER
ORGANIC WASTES & SLIME GROWTHS
KAISER GYPSUM
CROWN ZELLERBACH
LEGEND
WASTE-100,000 P.E.
SLIME GROWTH AREAS:
HEAVY
LIGHT
RIVER
PORTLAND SEWAGE
SAUVIE IS.
COLUMBIA RIVER PAPER
VANCOUVER SEWAGE
CANNING PLANTS
CROWN ZELLERBACH
BONNEVILLE DAM
CAMAS
PORTLAND

21b

and sulfate pulp mill digester liquors and of other organic materials, experience with slime growths in other streams, and knowledge of sources of organic wastes in the lower Columbia River combine to indicate that sulfite and sulfate pulp and paper mills are the principal cause of excessive slime growths in the lower Columbia.

It is probable that organic wastes other than those from pulp and paper mills contribute in a limited degree to the total quantity of slime growth in the Columbia. Of these the sewage from Portland and the wastes from canning plants in Vancouver are the principal individual sources of organic materials, accounting for about 7.5 per cent of the total P.E. from all sources. This is more than one-half of the estimated 12.8 per cent of the P. E. from all sources of wastes other than pulp and paper mills. The pulp and paper mill wastes, as noted earlier, account for the remaining 87.2 per cent of the total P.E.

It appears that no serious slime problem would occur in the lower Columbia River in the absence of pulp and paper mill pollution.

Table 3 gives the reported pulp production capacities of the mills in the area. These data are based on designed capacities rather than on actual production. It is rare that a plant produces at exact design capacity. When business is not good the plant may operate at less than design capacity. In good times production may be pushed to exceed design capacity by a significant percentage. It is reported, for example, that both the Weyerhaeuser Timber Company and the Longview Fiber Company plants at Longview, Washington, recently have been operating at greater than their designed capacities.

In spite of irregularities in production it is believed that the designed capacities provide a reasonable basis for evaluating the relative importance of the individual plants in the over-all pollution problem.

The growth of slimes has been associated principally with the digester liquor content of the pulp and paper mill wastes. The digester liquors contain most of the simple organic compounds that support the slime growths. Waste sulfite digester liquor, for example, may contain as much as 4 per cent of sugars and acetic acid.

In the study of waters involving pulp and paper mill wastes an analytical method based on a lignin reaction has become accepted as a means of determining approximate concentrations of digester liquors in the receiving waters. The comparison standard used in this determination usually is sulfite waste liquor, adjusted to a 10 per cent solids content. The results of determinations are reported as ppm of sulfite waste liquor with 10 per cent solids (S.W.L.). This affords a convenient, though admittedly not exact, means of comparing the pulp and paper mill wastes from all sources. Most of the studies of the Columbia River have included examination of river samples by this method.

Table 3

Reported* Pulp Production Capacity
Lower Columbia River

| Plant | Pulp in Tons Per Day | | | | |
|---|---|---|---|---|---|
| | Sulfite | Sulfate | Semi-Chemial | Ground or Mechanical | Totals |
| Crown Zellerbach Corp., Camas | 360 | 605 | - | 100 | 1,065 |
| Columbia River Paper Mills, Vancouver | 120 | - | - | - | 120 |
| Crown Zellerbach Corp - St. Helens (Formerly St. Helens Pulp & Paper Co.) | - | 375 | - | - | 375 |
| Kaiser Gypsum Co., Inc. - St. Helens (Formerly Fir-Tex Insulating Board Co.) | - | - | - | 145 | 145 |
| Longview Fiber Co., Longview | - | 702 | 46 | 39 | 787 |
| Weyerhaeuser Timber Co., Longview | 330 | 200 | 150 | - | 680 |
| International Paper Co., Longview (Formerly Long-Bell Lumber Co.) | - | - | - | 10 | 10 |
| Washington Pulp & Timber Co. Longview | - | - | - | 32 | 32 |
| Publishers Paper Co., Oregon City | 105 | - | - | 195 | 300 |
| Totals | 915 | 1,182 | 196 | 521 | 3,514 |

* Lockwoods Directory of the Pulp and Paper Industry.

Data on actual digester liquor volumes from the several mills on the lower Columbia River are not available for use in this report. Approximations of the volumes from those using chemical digestion processes are possible if certain assumptions are accepted as reasonable. It is realized that actual volumes of digester liquor vary from plant to plant and even from time to time in the same plant. The following assumptions are adopted as a basis for the approximations.

1. That both sulfite and sulfate pulp mills produce approximately 2,200 gallons of used digester liquor, with 10 per cent solids, per ton of pulp produced, and that the liquors from both types of mills are equivalent in materials that will support slimes.

2. That all sulfate pulp mills and magnesium base sulfite pulp mills recover 85 per cent of the used digester liquors.

3. That used semichemical digester liquor is recovered with used sulfate liquor, and that the combined strength and volume of semichemical digester liquor discharged per ton of pulp is equivalent to 15 per cent of the sulfite waste liquor discharged from a ton of calcium base sulfite pulp.

Table 4 has been computed on the basis of the above assumptions and the pulp production figures given in Table 3.

On this basis the Crown Zellerbach Corporation at Camas is the largest contributor of equivalent sulfite waste liquor, with 46.3 per cent of the total liquor discharged to the lower Columbia River. This company's plant at St. Helens is the smallest contributor, with an estimated 5.8 per cent of the total. The other four mills are fairly closely grouped, with contributions in the range of 10.6 to 13.5 per cent.

If the estimates in Table 4 are reasonable it is somewhat surprising that more concentrated growth has not been reported immediately below Longview, where the two mills there discharge a combined 22.1 per cent of the total.

Apparently some unknown combination of river characteristics permits the Longview wastes to produce intermittent light slime growth as far downstream as Cathlamet, rather than concentrated growth such as that which occurs below Camas and Vancouver.

The Lincoln and Foster report included the conclusion, as previously noted, that Sphaerotilus growth should not be excessive if S.W.L. concentrations in the Columbia were held below about 50 ppm. In 1951 and 1952 the plants of Crown Zellerbach Corporation, Columbia River Paper Mills, Longview Fiber Company, and Weyerhaeuser Timber Company installed waste diffusion lines to remove the discharges of digester liquor waste

Table 4

Estimated Equivalents of Waste Sulfite Digester Liquor
Discharged to Lower Columbia River

| | Est. Equivalent Sulfite Digester Liquor-Gals/Day | | | | |
|---|---|---|---|---|---|
| | Type of Pulp | | | | |
| | Sulfite | Sulfate | Semi-Chemical | Total | Per Cent of Total |
| Crown Zellerbach, Camas | 792,000 | 198,000 | | 990,000 | 46.3 |
| Columbia River Paper Mills, Vancouver | 264,000 | | | 264,000 | 12.3 |
| Crown Zellerbach, St. Helens | | 123,000 | | 123,000 | 5.8 |
| Longview Fiber, Longview | | 231,000 | 15,000 | 246,000 | 11.5 |
| Weyerhaeuser Timber, Longview | 110,000 | 66,000 | 50,000 | 226,000 | 10.6 |
| Publishers Paper, Oregon City | 288,000 | | | 288,000 | 13.5 |
| | 1,454,000 | 618,000 | 65,000 | 2,137,000 | 100.0 |

from the quiet waters near the river bank and to distribute them in the currents of the main river channel. These changes were made in an effort to control the slimes by reducing digester liquor concentrations to or below 50 ppm. These commendable efforts did not accomplish the desired results, and interference with fishing continues to be a problem.

The estimated volumes of equivalent sulfite waste liquor in Table 4 provide a basis for estimating possible concentrations of S.W.L. in the Columbia. As noted earlier, average monthly flows in the Columbia below Bonneville Dam often are as low as 80,000 cfs. In addition, diurnal control of flow by Bonneville Dam at times of peaking power operations during low flow periods results in flows during nights as low as 30,000 to 40,000 cfs for 7 to 9 consecutive hours. Possible concentrations of the estimated digester liquor volumes, as given in Table 4, completely diluted in 80,000 and 35,000 cfs are presented in Table 5.

Table 5

Estimated Concentrations of Waste
Digester Liquor at Minimum Flows
in the Lower Columbia River

| Source Of Digester Liquor | Equivalent S.W.L. - ppm | |
|---|---|---|
| | At 80,000 cfs | At 35,000 cfs |
| Crown Zellerbach, Camas | 19.1 | 43.8 |
| Columbia Paper Mills Company | 5.1 | 11.7 |
| Crown Zellerbach, St. Helens | 2.4 | 5.4 |
| Longview Fiber | 4.8 | 10.9 |
| Weyerhaeuser Timber | 4.4 | 10.0 |
| Publishers Paper Company | 5.6 | 12.7 |
| Total, All Sources | 41.4 | 94.5 |

These estimates indicate that the concentration of the total of all S.W.L., after complete dilution and mixture in a daily flow of 80,000 cfs, would be about 40 ppm. The computed concentrations make no allowance for the occurrence of higher localized concentrations before complete mixture and dilution of the wastes. For a few hours each night during a prolonged low flow period, when peaking power operations are in effect, the total of all S.W.L. could give a concentration nearly double the 50 ppm level. The Crown Zellerbach Corporation wastes at Camas alone could approach 50 ppm. It is not known whether intermittent, but regular, occurrence of the higher concentrations could support excessive slime growths. Experimental work on a laboratory scale has indicated that slimes do not grow well when fed intermittently with S.W.L. Other experiments have indicated, however, that the slimes may grow at concentrations of S.W.L. as low as 20 ppm.

It has been stated previously that Sphaerotilus needs a suitable attachment surface to produce large tufts and streamers. Much of the bottom of the lower Columbia River is composed of shifting sand, which apparently is not suitable for growth. Most of the attached growth observed has been on gravel and rocks on the side and bottom of the river channel, on log rafts, and on pilings, docks and other structures in the

river. Sphaerotilus also has been reported to be able to attach to and grow on the wood fibers, or pulp particles, which are discharged as one constituent of the wastes from pulp and paper mills. Data are not available for this report on pulp losses at the individual plants involved. It is known that all of them discharge some wood fibers to the river which may serve as attachment surfaces for Sphaerotilus growths.

It has been reported that waste discharged from each 100 tons of sulfite pulp produced is capable of growing 70 tons of Sphaerotilus. If the assumptions used in estimating the equivalent sulfite waste liquor in Table 4 be reasonable this indicates an equivalent sulfite pulp production from all chemical pulp mills in the area of 970 tons per day. On the basis of the above ratio this pulp production could support 680 tons of Sphaerotilus growth per day.

## Fishing

The bacterial slimes interfere with both commercial and sport fishing.

### Commercial Fishing

Gill nets are used for commercial fishing in the lower Columbia River. Some description of the gill net and its operation is necessary to an understanding of how the slimes interfere with its use.

There is no standard size net, but individual sections frequently are about 1,200 feet long and 6 to 8 feet wide. Two or more net sections may be tied together to provide a large net for fishing in deep or wide areas of the river.

The gill net, as commonly used, is not a single vertical net, but rather consists of three different portions. One portion is the main net, which may be one or more of the 6 to 8 by 1,200 foot sections mentioned above. The meshes of this net vary in size from about 3.5 inches up to 5 or 6 inches square. The second portion of the net is not so wide as the main net. This portion, attached to the top of the main net along its length, floats in front (downstream) of the main net, with the bottom of the front net unattached and maintaining an opening of several feet between it and the main net. This serves to prevent fish from swimming up and over the main net when they contact it. The third portion of the net is called a trammel. The meshes of the trammel net are large enough for the large fish to pass through. This net is also attached along the length of the top of the main net, and floats behind it (upstream). When a fish is too large for its gills to enter the smaller meshes of the main net the struggling fish pushes a portion of

the main net through the large meshes of the trammel net. This forms a pocket in which the fish is trapped.

The nets are made of linen, cotton, or nylon twine. All sections of the twine are knotted at top and bottom of the net, and at all points where vertical and horizontal lines cross to form the meshes. A single section of net may have over 100,000 knots.

The net has floats at the top and weights, or sinkers, at the bottom. The balance between the floats and sinkers may be such that the top of the net floats at the surface as it drifts downstream, in which case the net is called a "floater." This type of net cannot be adjusted to keep the bottom of the net near the irregular bottom of the river, and fish escape through the gap between the bottom of the net and the bed of the river. For this reason many fishermen prefer the "sinker" net. The balance of this net is delicately adjusted so that the net sinks until its bottom just touches the bottom of the river. The bottom of the net then tends to conform to the irregular bottom of the river as it drifts downstream, and prevents fish from escaping beneath it. The net floats in a nearly vertical position with its top slightly ahead (downstream) of its bottom.

When the twine of a net is fully flexible and the balance of the net is properly adjusted by an experienced fisherman the net acts almost like a live thing when a fish contacts it. The strands of the net wrap around and entangle the fish and the more the fish struggles the more tightly trapped it becomes.

The slimes interfere with the use of gill nets in several ways. As the net drifts downstream the slimes with which it comes in contact tend to become entwined with and adhere to the lines of the net. The slimes have a special tendency to tangle around the many knots of the net.

When quantities of slimes are not extreme much of the interference with fishing appears to result from the added resistance of the net to the water that is caused by the slimes. This reduces the liveliness of the net and its effectiveness in entangling the fish. It also affords more drag against the efforts of the fish to pull out of the net, and apparently increases the number that escape. Some fishermen believe the presence of slimes on a net increases the probability that fish will see the net and avoid it. Thus, moderate slimes reduce the numbers of fish caught.

Abundant drifting slimes may weight a net down and destroy the delicate balance necessary for successful fishing. Instead of floating in a nearly vertical position the top will tilt farther and farther ahead of the bottom of the net until it is nearly lying on the bottom of the river. The fish then pass over the net and escape.

The fisherman normally makes three to four drifts per day. When slimes are a problem it may be necessary to clean the net after each drift. This reduces the time that can be devoted to fishing. Sometimes the cleaning takes so much time that it is possible to make only one drift per day. Many methods of cleaning the nets have been tried, but picking the slime off the multitudinous knots by hand has been the most successful method found.

The drifting slimes are worse in some areas of the river than in others. Drifts where the problem is worse often have been abandoned by fishermen for a month at a time. Since commercial fishing is allowed for only 131 days per year the loss of a month of fishing time represents a serious loss of income to the fishermen.

The slimes also are reported to cause rotting of nets. The nets become weak at the knots, where the slimes are more difficult to remove completely. Even when a net is cleaned it is nearly impossible to remove all traces of slime from the innumerable knots. The residual slime clumps tend to keep the knots moist when the net is laid out to dry. This apparently affords an opportunity for microorganisms, of an unidentified type, to attack or rot the twine. Experienced commercial fishermen claim that the resulting rotting may shorten the life of even a well cared for nylon net by as much as one year of its normal three years of usefulness. Since a nylon net costs $1,500 to $2,000 this reduction in net life represents another serious financial loss to the fisherman. Linen nets are said to be affected even more seriously than nylon by the rotting attributed to slimes, and may last only a year. For this reason most fishermen use nylon nets even though they cost about three times as much as linen.

Under normal conditions a net should be treated about once a year with a disinfecting solution of a copper compound. When slimes foul the nets it may be necessary to use the copper solution as often as once a week.

It is reported that slimes grow on the bottoms of the commercial fishermen's boats below the water line. It is said that the accumulations of slime sometimes become so great that they actually reduce the speeds of the boats to the extent that it becomes necessary to remove them from the water and scrape off the slimes.

There are adequate pictures, records of complaints by fishermen, and personal observations of actual problems by reliable individuals to establish the fact that slimes in the lower Columbia River cause serious interference with commercial fishing, and financial loss to commercial fishermen. There has not been a sufficiently systematic recording of the magnitude, occurrence, and effects of interference to permit a reliable estimate of the actual financial loss involved.

There has been a marked decline in gill net licenses issued to Columbia River commercial fishermen since 1948. In that year 1,102 licenses were issued, compared to 792 in 1956. This represents a decrease of nearly 40 fishermen per year. No claim has been made that this continuing reduction can be attributed completely or even principally to the slime problem. The opinion has been expressed, however, that the difficulties caused by slimes may have been the final factor among several in the decisions of some of the commercial fishermen to give up this means of livelihood.

Since 1942 the annual commercial pack of Columbia River salmon has averaged about one-half of that in the years preceding 1942. The annual average pack for the 15 years since 1942 has been 194,000 cases, compared to 380,000 for the preceding 15 years. Here again there are so many factors involved in the reduction that it is not possible to access the portion attributable to the slime problem. There can be little doubt that the slimes have caused some portion of the reduction.

Sport Fishing

Sport fishermen complain that the slimes interfere with their success in taking fish.

The experienced sport fisherman attributes much of his success in catching fish to his knowledge of the exact spot where the fish are apt to pass in the river, and to his skill in placing his lure exactly on that spot. His complaints involve several problems presented by the slimes.

On the cast, while the line is settling through the water, the slimes attach themselves to the line. The resistance to the water caused by the added slime mass allows the current to sweep the line downstream from the spot at which the lure was aimed.

If the fisherman uses a heavier sinker to overcome the drag on the line caused by the slimes it is more difficult to feel the tug on the line when the fish bites. In addition the heavier sinker offers more resistance to the pull of the fish when it tries to escape, and the fish has a better chance of tearing loose from the hook.

Even when the fisherman is successful in placing the lure where he wants it the slimes may attach themselves to the lure and hide it from the fish.

Here again, as in the case of commercial fishing, systematic records are not available to allow evaluation of the quantitative impact of this problem. It has caused irritation and complaint on the part of sport fishermen whose pleasure in their sport has been lessened, and whose chances of maximum fishing success have been reduced.

## SUMMARY

The lower Columbia River, between Bonneville Dam and Cathlamet, Washington, is used for almost every purpose that a river can serve.

The river serves as the source of domestic and industrial water supply and of water for a small amount of irrigation. It is used for recreation, which includes boating, swimming, water skiing, fishing, waterfowl hunting, and a limited amount of trapping. The river has high scenic value. It supports navigation, involving transportation of large quantities of raw materials and finished products. The Columbia is an important spawning ground for anadromous fishes, and its salmon and steelhead trout provide a livelihood for commercial fishermen, and recreation for sport fishermen. The river carries away the liquid wastes produced by towns and industries along its banks.

The sewage and industrial wastes discharged to the Columbia produce conditions that conflict with some of the other uses of its waters. Many of the water quality objectives for protection of water uses adopted by the Pollution Control Council of the Pacific Northwest Area are not met.

Immediately below the Portland-Vancouver area coliform organisms from sewage are about 97 times the Pacific Northwest Area Pollution Control Council's water quality objective for water used for swimming. These bacteria decrease downstream to an estimated 11 times the objective at Cathlamet. Immediately below the Portland-Vancouver area the coliform organisms are 26 times the objective for water used for boating, fishing, and other activities involving similar contact with the water. At Cathlamet the bacterial concentrations are estimated to be 3 times the objective for these uses. In the area of the source of both domestic and industrial water supply for the Weyerhaeuser Timber Company at Longview it is estimated that the average concentration of coliform organisms originating in sewage discharged above Longview is twice the Council's objective for water used as a source of domestic water supply with the type of water treatment provided. Sewage discharged from Longview above the water intake is estimated to increase the average coliform concentration to nearly 4 times the objective.

Nearly 93 per cent of the bacterial contamination responsible for these violations of water quality objectives is from sewage discharged in the Portland-Vancouver area. It is estimated that nearly 97 per cent of the combined contamination from the Portland-Vancouver area is from Portland sewage.

Organic wastes discharged to this section of the Columbia support growths of non-pathogenic bacterial slimes (Sphaerotilus). These slimes, growing in profuse quantities in certain areas, break loose and drift down the river to foul the gill nets of commercial fishermen and the

lines and lures of sport fishermen. The drifting slimes interfere with both types of fishing from just below Camas all the way downstream to the mouth of the Columbia. The slimes cause a financial loss to commercial fishermen and reduce the pleasure of sport fishing.

All evidence points to pulp and paper mills which use chemical pulping processes as the principal sources of wastes that provide the nutrients on which the slimes grow. Areas in the river where the growing slimes have been observed are all on the Washington side of the river below the Crown Zellerbach Corporation pulp and paper mill at Camas, the Columbia River Paper Mills at Vancouver, and the Longview Fiber and the Weyerhaeuser Timber Company pulp and paper mills at Longview. The Publishers Paper Company at Oregon City, Oregon, contributes to the problem by barging most of its sulfite waste liquor to and discharging it in the Columbia below the mouth of the Willamette during the months of July through October. The Crown Zellerbach Corporation mill at St. Helens discharges a relatively small amount of digester liquor to the river on the Oregon side but in passing downstream this may supplement the wastes from the Longview area and contribute to the sustained growth for many miles below Longview.

It is evident that pollution of the Columbia River between Camas and Cathlamet, Washington, constitutes pollution of interstate waters subject to abatement under the Federal Water Pollution Control Act as such pollution endangers the health and welfare of persons in States other than those in which the discharges contributing to such pollution originate.

# APPENDIX

## Table I

### Bacterial Population Equivalents of Sewage Discharged To Lower Columbia River

| Source | Treatment | Sewered Population | Bacterial Pop. Equivalent Number | Bacterial Pop. Equivalent Percent of Total |
|---|---|---|---|---|
| **Oregon** | | | | |
| Clatskanie | Intermediate-Chlorination | 800 | 80 | 0.05 |
| Rainier | None | 1,200 | 1,200 | 0.77 |
| St. Helens | None | 4,500 | 4,500 | 2.88 |
| Portland | Primary | 280,000 | 140,000 | 89.57 |
| Portland Airport | Primary-Chlorination | 3,000 | 300 | 0.19 |
| Gresham | Primary-Chlorination | 3,000 | 300 | 0.19 |
| Troutdale Multnomah County Farm | Secondary | 1,000 | 100 | 0.06 |
| Reynolds Aluminum Company | Primary | 500 | 250 | 0.16 |
| Total Oregon | | 294,000 | 146,730 | 93.87 |
| **Washington** | | | | |
| Cathlamet | None | 650 | 650 | 0.42 |
| Kelso | Primary-Chlorination | 8,000 | 800 | 0.51 |
| Longview | " " | 24,000 | 2,400 | 1.54 |
| International Paper Company | " " | 400 | 40 | 0.03 |
| Longview Fiber Company | " " | 570 | 60 | 0.04 |
| Reynolds Aluminum Plant | " " | 120 | 10 | Negligible |
| Weyerhaeuser Timber Company | " " | 1,000 | 100 | 0.06 |
| Kalama | " " | 1,000 | 100 | 0.06 |
| Woodland | " " | 1,000 | 100 | 0.06 |
| Vancouver | " " | 40,550 | 4,060 | 2.60 |
| " | None | 700 | 700 | 0.45 |
| Aluminum Company of America | Primary-Chlorination | 430 | 40 | 0.03 |
| Camas | " " | 5,200 | 520 | 0.33 |
| Washougal | " " | | | |
| Washougal Woolen Mill | | 180 | 20 | Negligible |
| Total Washington | | 83,800 | 9,600 | 6.13 |
| Total All Sources | | 377,800 | 156,330 | 100.0 |

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Table II

Oxygen Demand Population Equivalents of Sewage and Industrial Wastes Discharged to Lower Columbia River

| Source | Population Equivalent | | | |
|---|---|---|---|---|
| | Sewage | | Industrial Wastes | |
| | Number | Per Cent of Total | Number | Per Cent of Total |
| Oregon | | | | |
| Clatskanie | 320 | Negligible | - | - |
| Rainier | 1,200 | 0.04 | - | - |
| St. Helens | 4,500 | 0.14 | - | - |
| Kaiser Gypsum Co., Inc. | - | - | 100,000 | 3.11 |
| Crown Zellerbach Corp. | - | - | 150,000 | 4.66 |
| Portland | 218,000 | 6.78 | - | - |
| Associated Meat Packers | - | - | 4,800 | 0.15 |
| Columbia Wool Scouring Co. | - | - | Unknown | - |
| Pacific Meat Company | - | - | 2,000* | 0.06 |
| Portland Airport | 2,100 | 0.07 | - | - |
| Portland Rendering Company | - | - | 500* | 0.01 |
| Portland Union Stockyard | - | - | 1,000 | 0.03 |
| Swift and Company | - | - | 9,000 | 0.28 |
| Gresham | 5,900 | 0.18 | - | - |
| Troutdale | | | | |
| Bissinger and Company | - | - | Unknown | - |
| Multnomah County Farm | 200 | Negligible | - | - |
| Reynolds Aluminum Company | 350 | 0.01 | - | - |
| Total Oregon | 232,570 | 7.22 | 267,300 | 8.30 |
| Washington | | | | |
| Cathlamet | 650 | 0.02 | - | - |
| Kelso | 5,200 | 0.16 | - | - |
| Central Smelt Company | - | - | Unknown | - |
| Longview | 16,000 | 0.50 | - | - |
| International Paper Company | 400 | 0.01 | - | - |
| Longview Fiber Company | 400 | 0.01 | 216,000 | 6.72 |
| Longview Meat Packing Company | - | - | 300 | 0.09 |
| Reynolds Aluminum Plant | 120 | Negligible | - | - |
| Weyerhaeuser Timber Company | 700 | 0.02 | 407,000 | 12.66 |
| Kalama | 700 | 0.02 | - | - |
| Woodland | 700 | 0.02 | - | - |

* Estimated - subject to future check and correction.

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Table II (Con't.)

Oxygen Demand Population Equivalents of Sewage and Industrial Wastes Discharged to Lower Columbia River

| Source | Population Equivalent | | | |
|---|---|---|---|---|
| | Sewage | | Industrial Wastes | |
| | Number | Per Cent of Total | Number | Per Cent of Total |
| Washington (Con't.) | | | | |
| Vancouver | 29,150 | 0.90 | - | - |
| Aluminum Company of America | 430 | 0.01 | - | - |
| California Packing Company | - | - | 76,000* | 2.36 |
| Columbia River Paper Mill | - | - | 431,000 | 13.40 |
| Great Western Matting Company | - | - | 5,200 | 0.16 |
| Vancouver Plywood Company | - | - | 130 | Negligible |
| Washington Canners Corporation | - | - | 20,500* | 0.64 |
| Camas | 3,640 | 0.11 | - | - |
| Crown Zellerbach Corporation | - | - | 1,500,000 | 46.66 |
| Washougal | 120 | Negligible | 450 | 0.01 |
| Washougal Woolen Mills | | | | |
| Total Washington | 58,210 | 1.78 | 2,656,580 | 82.70 |
| Total All Sources | 290,780 | 9.00 | 2,923,880 | 91.00 |

* Estimated - subject to future check and correction.

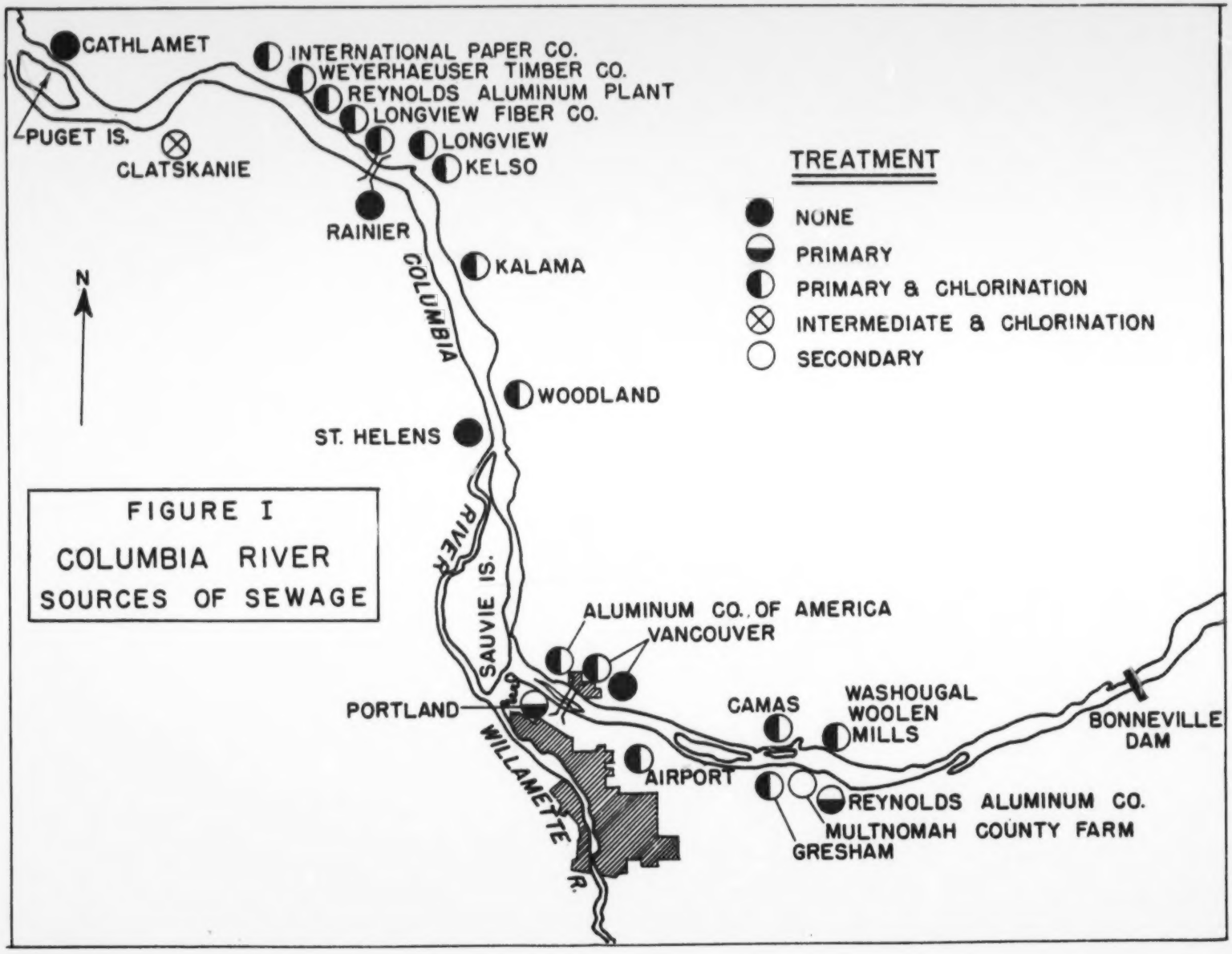
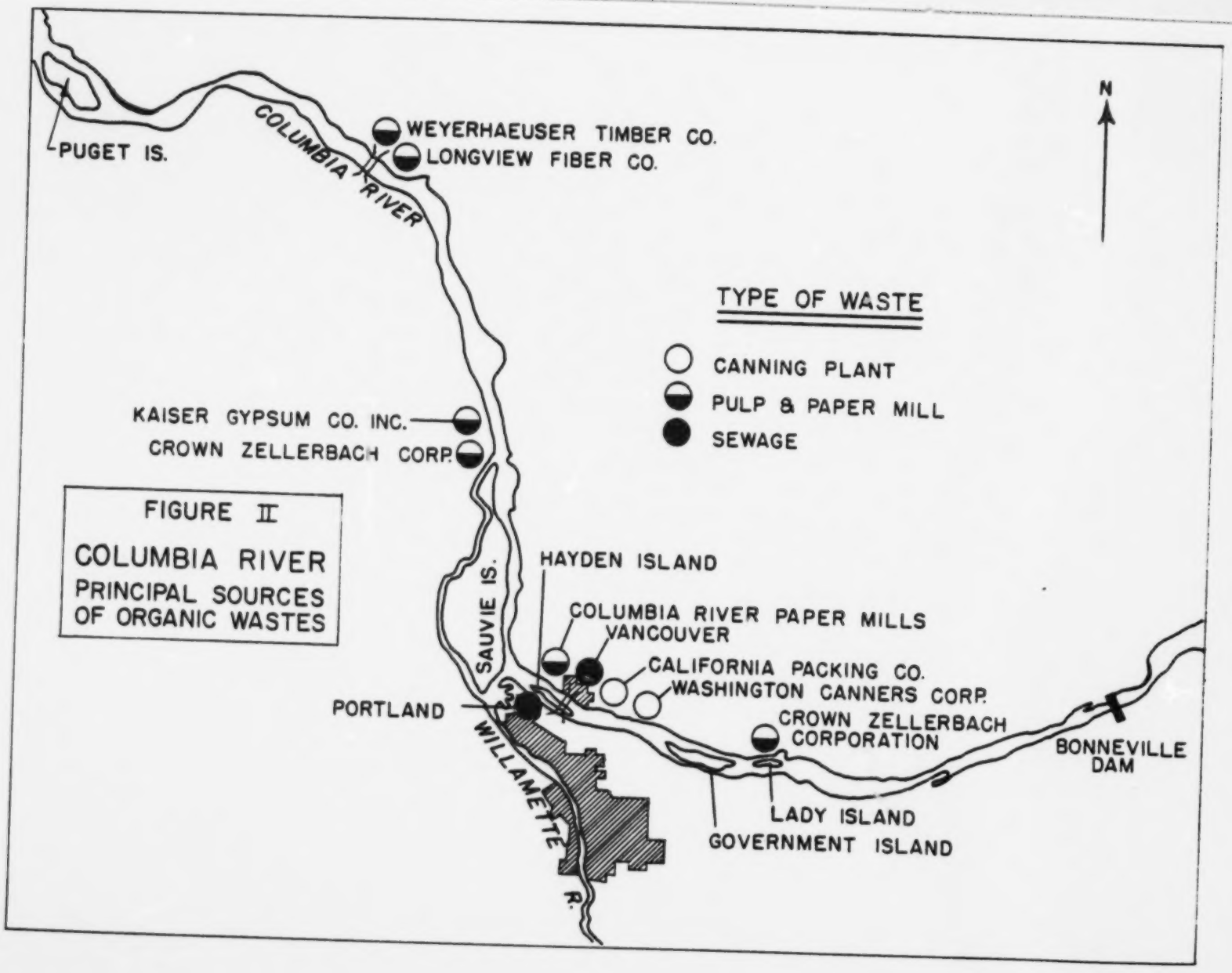



FIGURE I
COLUMBIA RIVER
SOURCES OF SEWAGE


N
PUGET IS.
COLUMBIA RIVER
WEYERHAEUSER TIMBER CO.
LONGVIEW FIBER CO.
TYPE OF WASTE
CANNING PLANT
PULP & PAPER MILL
SEWAGE
KAISER GYPSUM CO. INC.
CROWN ZELLERBACH CORP.
FIGURE II
COLUMBIA RIVER
PRINCIPAL SOURCES
OF ORGANIC WASTES
SAUVIE IS.
HAYDEN ISLAND
COLUMBIA RIVER PAPER MILLS
VANCOUVER
CALIFORNIA PACKING CO.
WASHINGTON CANNERS CORP.
PORTLAND
WILLAMETTE R.
CROWN ZELLERBACH
CORPORATION
BONNEVILLE
DAM
LADY ISLAND
GOVERNMENT ISLAND